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Effect of Insecticides on Natural-Enemies

Mohamed Abdel-Raheem

Abstract

Pesticides management options for control of invertebrate pests in many parts of the world. Despite an increase in the use of pesticides, crop losses due to pests have remained largely unchanged for 30–40 years. Beyond the target pests, broad-spectrum pesticides may affect non-target invertebrate species, including causing reductions in natural enemy population abundance and activity, and competition between pest species. Assays of invertebrates against weathered residues have shown the persistence of pesticides might play an important part in their negative impacts on natural enemies in the field. A potential outcome of frequent broad-spectrum pesticide use is the emergence of pests not controlled by the pesticides but benefiting from reduced mortality from natural enemies and competitive release, commonly known as secondary pests.

Keywords: effect, insecticides, natural enemies

1. Introduction

Pesticides management options for control of invertebrate pests in many parts of the world [1, 2]. Despite an increase in the use of pesticides, crop losses due to pests have remained largely unchanged for 30–40 years [3]. Beyond the target pests, broad-spectrum pesticides may affect non-target invertebrate species [4], including causing reductions in natural enemy population abundance and activity [5, 6], and competition between pest species [7]. Assays of invertebrates against weathered residues have shown the persistence of pesticides might play an important part in their negative impacts on natural enemies in the field [8].

A potential outcome of frequent broad-spectrum pesticide use is the emergence of pests not controlled by the pesticides but benefiting from reduced mortality from natural enemies and competitive release, commonly known as secondary pests [9–11]. Secondary pest outbreaks are challenging as they may also be caused by other mechanisms, which inherently make it difficult to determine how frequently pesticide use results in this outcome [10]. In cotton fields, it was estimated that 20% of late-season pesticide costs were attributable to secondary pest outbreaks caused by early-season pesticide applications for *Lygus* pests [10]. Higher numbers of cotton aphids, *Aphis gossypii* Glover and spider mites, *Tetranychus urticae* Koch were found in cotton fields that received early-season applications of insecticides against *Helicoverpa* spp. [5, 6].

One standardized approach for assessing non-target impacts of pesticides is the International Organization for Biological and Integrated Control—Pesticides and Beneficial Organisms (IOBC) rating system [12–14]. Subsequently, more bioassays

under field conditions are needed to incorporate the dynamic interaction between pest populations and their natural enemy communities [15] and the environmental context at the time of application [16–18].

In Australian broad-acre grains the pest management practitioners are primarily concerned with pesticide efficacy, crop phytotoxicity, and cost; seldom are broader impacts of pesticides included in decision-making [19–21]. Chlorpyrifos is applied for the control of pests such as earwigs, isopods, and millipedes (Portuguese millipede, *Ommatoiulus moreleti* Lucas, 1860) [15], despite not being registered specifically to control those pests. A reduced application rate of broad-spectrum pesticides may lessen the impact on natural enemies but remain efficacious against pests [5, 22]. Repeated applications of broad-spectrum pesticides to control typical pest species are common in broad-acre crops, in particular canola [21] and pulses [23], therefore growers cannot often relate the pest numbers observed in a field to likely yield losses and adjust pesticide application [24]. The outcome is that pesticides are often applied prophylactically or in response to some observed crop damage that may or may not result in yield loss.

2. Indirect effects of pesticides on natural enemies

The indirect effects of pesticides on natural enemies have not been studied as extensively compared to direct effects, this chapter presents the indirect effects of pesticides that have primarily involved evaluating fecundity and longevity [25–35].

Prey consumption is the most important to successfully integrating natural enemies with pesticides and prevents indirect consequences on population dynamics [36, 37].

Some factors affiliated with natural enemies that may influence the indirect effects of pesticides include natural enemy age, type of natural enemy, life stages exposed to pesticides, and sex [38, 39]. Indirect affect may be related to residues remaining after a foliar application [40, 41]. Residues remaining after application may indirectly affect parasitoids by inhibiting adult emergence [42].

Natural enemies, indirectly affected by feeding on contaminated honeydew excreted by phloem-feeding insect prey [43, 44]. Certain pesticides may also exhibit repellent activity [45, 46] or alter host plant physiology [47, 48] indirectly affecting the ability of natural enemies to regulate existing arthropod pest populations [49].

3. Systemic insecticides

Applied as granules have been promoted to be relatively non-toxic to natural enemies [49–51]. However, insecticides as systemic effect exhibit indirect effects against natural enemies via several mechanisms of prey floral parts contaminated with the active ingredients [52–54]. Systemic insecticides may indirectly influence natural enemies if the mortality of prey populations is high [55, 56].

Natural enemies decrease the populations during starvation or dispersal [55, 57–59]. This effect depends on the foraging efficiency of the specific natural enemy. Decrease quantity or density of available prey or decrease their quality such that they are not acceptable as a food source, indirectly affected on larvae and adults or female parasitoids not lay eggs. Reproduction, foraging, fecundity, and longevity [33].

The active ingredient of systemic insecticide is distributed into flower parts indirectly impact natural enemies that feed on plant pollen or nectar such as minute pirate bug, *Orius* spp., which feed on plants during their life cycle [60–62], After feeding on the nectar of buckwheat (*Fagopyrum esculentum*) plants adults of, *Anagyrus pseudococchi*

are indirect affect [53]. *Microplitis croceipes* after feeding on the extrafloral nectaries of cotton plants was decreased foraging ability and longevity [63]. The application method and possibly timing of application may influence any indirect effects on parasitoids that feed on flower pollen and nectar as a food source [63]. Translocation of systemic insecticides into flowers indirectly affect natural enemies by altering foraging behavior as has been shown with the pink lady beetle, the green lacewing, and the parasitoid, *A. pseudococci* [53, 62]. The ability of systemic insecticides, when applied to the soil or growing medium as a drench or granule, to move into floral parts contingent on water solubility, application rate, and plant type [38, 63].

4. Insect growth regulators

Insect growth regulators are active directly on immature stages of some insect pests, there are three types of insect growth regulators: juvenile hormone mimics, chitin synthesis inhibitors, and ecdysone antagonists [64–69].

4.1 Pyriproxyfen

Pyriproxyfen, a juvenile hormone mimic is not indirect harmful effects against adult female oviposition and egg viability of green lacewing, *C. carnea* [70–72]. Also, not indirect effects on development time, female longevity, and fertility of *Orius* sp. [72]; exposure to pyriproxyfen delayed development and decreased the rate of parasitism of, *Hyposoter didymator* [73], and demonstrated to substantially alter of development time on *Chrysoperla rufilabris* of immatures [74], also, did not indirect impact against *Delphastus catalinae* female fecundity [70].

Fifth instars of *Podisus maculiventris* exposure to pyriproxyfen did not an indirect effect against reproduction. *Encarsia pergandiella* and *Encarsia transvena* are not indirect affect after exposure while *Encarsia formosa* exhibited decreased rates of emergence [75].

4.2 Kinoprene

Kinoprene is indirectly harmful against natural enemies by inhibiting adult emergence of, *Opius dimidiatus* and *Aphidius nigripes* [76, 77]. Kinoprene did not indirectly affect parasitoid emergence from *Planococcus citri* mummies [78]. Also, it inhibits adult emergence against some parasitoids [79].

4.3 Fenoxycarb

It is a juvenile hormone analog [80, 81] that has shown to be indirectly harmful to some natural enemies. It is delay development time from of pupae and adult of *C. rufilabris* [81], also, delay development of third instar larvae but not first instar larvae. Also, reproduction of females is inhibiting when second and third instars were initially exposed to it [82, 83]. Also, the same result against third instar larvae of *C. carnea* [84]. Also, happened indirect affect against female longevity and fecundity of, *Micromus tasmaniae* [74].

4.4 Cyromazine

It is a growth regulator that disrupts molting, it is affecting cuticle sclerotization during increasing cuticle stiffness [65], and exhibits indirect effects on the reproduction of *Phytoseiulus persimilis* [74], no indirect effect, against rates of adult

emergence, of *Chrysocharis parksi* [85]. Exposure to it did not indirectly affect on longevity and reproduction of, *Hemiptarsenus varicornis* and *Diglyphus isaea* [86].

4.5 Diflubenzuron

It is a chitin synthesis inhibitor [65], less indirect impact against natural enemies, both parasitoids and predators [87].

Exposure to it decreased female longevity and reduced the parasitization rate of, *Hyposoter didymator* [73] and reproduction of, *Eulophus pennicornis* [88].

M. tasmaniae, exposed to diflubenzuron, resulted in indirect affects on reproduction, sex ratio, and longevity [74]. Diflubenzuron exhibited no indirect effects on the reproduction of, *Podisus maculiventris* adults. Diflubenzuron displayed minimal indirect effects on the parasitoid, *Macrocentrus ancyliivorus* [89].

4.6 Buprofezin

It is a chitin synthesis inhibitor [66, 90], sterilizes certain natural enemies [91], reduces the number of progeny per female and sex ratios [73]. Feeding on it decreases female fertility and fecundity, and sterilized the males of the predatory coccinellid, *Delphastus catalinae* [69]. It did not affect the development of *Orius tristicolor* [92] or inhibits the reproduction of females of, *P. persimilis* [74]. Also, no indirect affect on oviposition and foraging of some parasitoids as *Eretmocerus* sp., and *Encarsia luteola* [90, 93]. Insect growth regulators are susceptible to early instars [90, 94, 95].

Indirect effects on natural enemies due to the volatility of the compound as it is known to be volatile and display vapor activity on some insect pests [96].

4.7 Azadirachtin

It is an ecdysone antagonist [72, 97–101], indirect effects against natural enemies [102]. It inhibits oviposition of the green lacewing, *C. carnea* and indirect affect against fertility and fecundity [99, 100]. Reproduction of, *Aphidoletes aphidimyza* is not indirect affect after exposure to it [103], and did not indirectly affect on the fecundity of, *Aphidius colemani* [91]; longevity and foraging ability of the parasitoids, *Cotesia plutellae* and *Diadromus collaris*, and sex ratio of progeny [6]; nor a reproduction of, *Neoseiulus californicus* [104]. Also, do not inhibit prey consumption of, *Atheta coriaria* adults [105].

First larvae of *Harmonia axyridis*, exhibit increase of development time, also, no indirect effect on adult fecundity [106–108].

5. Selective feeding blockers

It is include flonicamid and pymetrozine, inhibits feeding activity of piercing-sucking insects after initial insertion of their stylets into plant tissues and interfere with neural regulation of fluid intake through the mouthparts resulting in starvation [102, 109–112]. Flonicamid and pymetrozine, did not affect the development time, fertility, and parasitism of natural enemies, *Episyrphus balteatus*, *Bembidion lampros*; *Aphidius rhopalosiphi*, *Adalia bipunctata*; and *Aleochara bilineata* [112]. Pymetrozine exhibited minimal indirect effects on the reproduction of *N. californicus* [104]. Flonicamid did not indirectly affect parasitism, the sex ratio, and adult emergence of the parasitoid, *L. dactylopii*. Overall, minimal research has been conducted to determine the indirect effects of these types of pesticides on natural enemies [113].

6. Microbials

Entomopathogenic fungi and bacteria are, in general, not indirectly harmful to natural enemies, this may vary depending on concentration, natural enemy type, life stage exposed, the timing of application, and environmental conditions [114, 115].

Indirect effect not be associated with entomopathogenic fungi or bacteria [116]. *B. thuringiensis* has been indirect effects on some parasitoids this is depended on the formulation [117].

Natural enemies ingest fungal spores during grooming or feeding on contaminated hosts [89]; also, indirect effects depend on the concentration of spores [118]. Entomopathogenic fungi indirectly affect some natural enemies during feeding on prey that have been sprayed. Larvae of, *Cryptolaemus montrouzieri* were killed (50% mortality) after consuming mealybugs that had been sprayed with *Beauveria bassiana* [115]. *B. bassiana* decreased the fecundity of *N. californicus* females [104]. Fungus *Cephalosporium lecanii* exhibited no indirect effects on the longevity of the leafminer parasitoid, *Diglyphus begini* [119]. Exposure to *Metarhizium anisopliae* had no indirect effect on prey consumption (fungus gnat larvae) of rove beetle, *A. coriaria* adults [101]. Exposure to *Isaria* (= *Paecilomyces*) *fumosoroseus* at low relative humidity (55%) resulted in no indirect effects on foraging behavior and longevity of the aphid parasitoid, *Aphelinus asychis* whereas both parameters were significantly reduced when exposed to a high ($\geq 95\%$) relative humidity, which could impact the ability of the parasitoid to regulate aphid populations. Ovipositing females may avoid prey that is infected by entomopathogenic fungi [114].

Spinosad has been demonstrated to be indirectly harmful to a variety of predatory insects such as, *C. carnea* [120]; *Hippodamia convergens*; *Orius laevigatus*, *Geocoris punctipes*; and *Nabis* sp. [121, 122]. Exposure to spinosad extended development time from the first instar to adult and decreased fertility of *Harmonia axyridis* females. Nevertheless, exposure to spinosad did not inhibit foraging behavior and reproduction of *P. persimilis* females [123, 124]. Parasitoids may be indirectly affected by spinosad based on decreased reproduction and reduced longevity [125, 126].

7. Miticides

It is like other pesticides, demonstrate variability in regards to any indirect effects against natural enemies depending on the type of miticide and predatory mite species [127]. It did not affect *Neoseiulus* (= *Amblyseius*) *womersleyi* on *Tetranychus urticae*, eggs [127, 128]. Exposure to concentrations of fenpyroximate indirectly affect on longevity and fecundity of *P. plumifer* [129]. Pyridaben inhibited reproduction of *Galendromus occidentalis* [130]. No indirect effects associated with sex ratio and prey consumption of *P. persimilis* [131, 132].

Exposure to bifenazate did not reduce fecundity, longevity, or prey consumption of *P. persimilis* or *N. californicus* [133].

8. Fungicides

It is considered low harmful to natural enemies comparing with insecticides and miticides [134]. Mancozeb was negatively affected against fecundity and reproduction of, *Amblyseius andersoni*, *G. occidentalis* [135], and *Euseius victoriensis* and inhibited the reproduction of, *Amblyseius fallacis* [130, 136]. Also, it did not

indirectly affect on longevity or reproduction of, *Hemiptarsenus varicornis* and *Diglyphus isaea* [55]. Fungicides did not indirectly affect the fecundity of both *E. victoriensis* and *G. occidentalis* [130].

9. Additional factors associated with indirect effects of pesticides on natural enemies

The methodology evaluates the indirect effects of pesticides on natural enemies that may influence the results obtained [136–144]. The indirect effects of pesticides against natural enemies not necessarily are affiliated with the active ingredient [136, [141–144]. It can be formulations as emulsifiable concentrates (EC) and soluble powders (SP) contain additives as adjuvants, surfactants, solvents, or carriers that are indirectly harmful to natural enemies [145].

10. Summary

This chapter has demonstrated the feasibility of combining or integrating natural enemies with certain pesticides including systemic insecticides, insect growth regulators, selective feeding blockers, microbials, miticides, and fungicides. There are three primary means by which natural enemies integrated with pesticides including pesticide selection, spatial separation of natural enemies and pesticides, and temporal discontinuity between natural enemies and pesticides [114]. Indirect effects are evaluated to determine if pesticides are compatible with natural enemies [29]. Indirect effects depending on concentration, natural enemy species, pesticide exposure time, developmental life stage(s) evaluated, and the influence of residues and repellency [50].

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